Mainstreaming PV as a Distributed Energy Resource

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ABSTRACT

Photovoltaic technology has developed sufficiently in a number of key areas so that it is a candidate for serious consideration as a distributed energy resource (DER) technology of choice. Efforts to this end are ongoing and are important because of the potentially significant market opportunities that may result. In addition, PV can serve as a model for other emerging distributed energy resources. Because PV and other DER are complementary but serve different markets, removal of implementation barriers for DER in general will have a positive impact on the PV industry. With support from the DOE PV program, significant advances have been made in the areas of performance, cost, and lifetime of PV modules, system design criteria, energy storage criteria, safety codes and standards, and the development of reliable power electronic components. It has been recognized that corresponding levels of sustained effort are required to assure reliability in the areas of system design, integration, and performance. Consequently a PV systems reliability effort has been initiated. As a result of these activities, PV is positioned as one of the more mature alternative DER technologies.

1. Introduction

Sandia is working in a variety of areas with key industrial partners to continue to position PV to be a technology of choice for DER. DOE is working to accelerate this change in the manner in which power is produced and distributed. These activities are highly synergistic in that successful approaches in PV can be readily extended to other DER. Improving the technology, identifying and addressing research gaps, and removing implementation barriers to all technologies is critical to achieving DOE's goal of having DER constitute 20% of capacity additions by 2010. [1] Therefore, Sandia is applying PV lessons learned to the broader arena of DER in general.

2. Inverters – the common DER utility interface

Power electronic inverters are critical system components that are integral to a variety of DER. Power generation sources using inverters include PV, fuel cells, most microturbines, and variable-speed wind generators. DER systems using energy storage also employ inverters. This is significant because energy storage can add value to DER by providing power during utility outages, improving transient load capabilities, improving power quality, and stabilizing local grids during utility perturbations. Inverters condition the electrical output of sources into utility-standard 60-Hz ac that is compatible with the grid and with existing electrical devices. As such, they serve as the interface between the source and the utility. Source power may be dc (fuel cells, PV, batteries) or ac at other than 60 Hz (microturbines, variable-speed windturbines). The performance characteristics of a wide variety of inverters have been evaluated at Sandia. This experience is used to identify required improvements to the technology and to work with manufacturers to implement those improvements. The fact that power electronics are common to ("cross-cut") the different DER technologies makes this experience valuable to their development and gives PV a position of leadership in this area.

3. PV-DER Objective and approach

The objective of the PV-DER work at Sandia is to make photovoltaics a preferred electrical energy supply option for distributed energy applications. The approach is to partner with industry and users of the technology such as the United States Department of Agriculture's Rural Utility Service (RUS), tribal authorities, state and federal governments, and coops/utilities to ensure customers are ready and able to make use of PV technology whenever the economics or other drivers dictate that they should. Where appropriate, costs are being shared using Cooperative Research and Development Agreements (CRADA). Such cooperative projects may include one or more of the following.

1) Define requirements – learn where the users of the technology perceive a need, including working with electric utilities to understand their motivation to be involved with PV.
2) Work with users to develop a reasonable system specification
3) Quantify system economics, including and emphasizing maintenance costs
4) Characterize the system components and the overall system in the distributed energy technologies testing laboratory, feeding the results back to the equipment manufacturers so they can evolve their products accordingly
5) Work with users and industry to develop the most effective installation and procurement methods

4. Four elements crucial to PV/DER

PV program experience has shown that having four elements in place can greatly accelerate successful technology development and implementation. All four are presently being pursued within the PV program. Sandia plans to coordinate input from end users, industry, and utilities to continue to refine and develop these elements. They are: 1) existing interconnection standards, 2) standardized type testing, 3) demonstrated control functionality, and 4) a technology reliability program. Ongoing efforts in these four areas are discussed below.

4.1. PV/Utility Interconnection Standard

Islanding – the unintended energizing of a section of the power system following a loss of utility – continues to be the most common concern of utility engineers. This issue has been dealt with effectively for PV by IEEE standard 929-2000 [2]. The standard, which includes test procedures developed at Sandia, was approved in January 2000 and is mandated by a number of states. Although it was intended to provide a straightforward procedure for approval of the utility interconnection of PV systems smaller than 10 kW, it has been required for larger units by a variety of utilities. It is also being referenced in testing for other DER sources such as microturbines. A number of the concepts are being incorporated into IEEE P1547 [3], an interconnection recommended practice being developed for all types of DER. Repeatedly, the lack of approved interconnection procedures has been cited as the single greatest barrier to the implementation of DER. In the case of PV, the existence of IEEE 929-2000 has greatly eased the interconnection approval process.

4.2. Standardized Type Testing

Test protocols are necessary for meaningful performance evaluations and comparisons. An example of a standardized test protocol is Appendix G of IEEE 929, which defines the requirement for a "non-islanding inverter." Underwriters Laboratories tests and certifies inverters using this methodology as documented in UL1741. Sandia is currently testing multiple parallel PV inverters per this procedure. This test is not a requirement of IEEE 929 but is being performed to "continue to expand our knowledge base and to ensure that the single-inverter test is adequate for new inverter models." [4] Islanding tests as well as detailed standardized performance evaluations are being performed in Sandia's Distributed Energy Technology Laboratory (DETL) for PV inverters in combination with microturbines, reciprocating generators, and fuel cells.

4.3. Control Functionality

Sandia's work in the PV controls area includes the development of an active algorithm to detect loss of utility under any load scenario. This algorithm is published in open literature [4] and is applicable to other DER sources in addition to PV. A second area of controls work concerns the operation of multiple sources in an isolated, i.e., not utility-connected, microgrid. Such a configuration would provide power during a utility outage and as such would provide added value that could expand the DER market significantly. Experience in PV-hybrid systems is valuable in this regard since an isolated microgrid constitutes a hybrid system. Sandia is developing prototype controls for microgrid operation and plans to test the prototype during FY02. A related capability is that of seamless transfer to and from the grid. Sandia developed a circuit technique utilizing energy storage that has evolved into a successful commercial product targeting customers requiring high power quality. This same technique is being examined for application to stabilize microgrids during utility fluctuations.

4.4. PV Reliability Program

In FY 2001 the DOE directed Sandia "to develop, in cooperation with industry, a systems and balance of systems (BOS) reliability". Key elements include establishing consistent program management and oversight and accelerating the development of a performance/reliability database. The program is structured to prioritize and examine the following issues:

- Define system lifetimes.
- Utilize systems engineering design approach.
- Investigate field-aged systems in detail. Initiate R&D programs with industry to solve particular problems.
- Expand laboratory test program that supports industry.
- Systematically document & analyze field reliability

Testing will be used throughout the development cycle to improve new-product reliability. The program will also encourage development of codes and standards, certification processes, and education and training.

5. PV taking the lead to fill DER "gaps"

The area of DER is so broad that its organization has required a great deal of effort from DOE and other agencies. A primary goal has been to identify research "gaps" which could most productively use additional effort to assist the maturation of the technologies. A. D. Little recently performed a study under contract to the California Energy Commission to identify strategies, categorize projects, and identify gaps. [5] The study suggested one approach to prioritizing DER strategies. The two strategies that were most highly prioritized using the suggested methodology are:

1) Type testing and certification of interconnection standards
2) Developing communications/control standards/protocols

This study underscores the importance of the areas in which the DOE PV program has already been and continues to be highly active.

6. References

[1] "Strategic Plan for Distributed Energy Resources," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy and Office of Fossil Energy, September 2000.

[2] "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems", IEEE Std. 929-2000.

[3] "Draft Standard for Interconnecting Distributed Resources with Electric Power Systems," IEEE P1547/D07, February 9, 2001.

[4] "Development and Testing of an Approach to Anti-Islanding in Utility-Interconnected Photovoltaic Systems," J. Stevens, et al, Sandia Report SAND200-1939, August, 2000.

[5] "Strategic Distributed Energy Resources Research Assessment" for California Energy Commission PIER Program, interim report, A.D. Little - August 16, 2001